NOTES, ABSTRACTS, AND REVIEWS.

ON THE RELATION BETWEEN THE MOVEMENTS AND THE TEMPERATURES OF THE UPPER ATMOSPHERE.

By V. BJERKNES.

[Abstracted from Comptes Rendus, Paris Academy of Sciences, vol. 170, pp. 604–606, Mar. 8, 1920.]

That the temperature of the lower layers of the atmosphere decreases from the Equator toward the poles is well known, as is also the cause of this decrease and its relation to the winds of the planetary circulation. Aerological investigations have disclosed the fact, however, that the temperature of the upper strata of the atmosphere increases from the Equator toward the poles.

That this latter phenomenon is a necessary consequence of the surface conditions may be shown by considering the earth and its atmosphere as one system, symmetrical with respect to the axis of the earth, around which the whole system rotates. From the well-known differential equations for the equipotential surfaces as modified by centrifugal force, it follows that in a stratum of air which has the same angular velocity as has the earth, the isobaric surfaces will coincide with "level" surfaces parallel to the surface of the earth; while if the angular velocity of the stratum be greater, these surfaces will not be parallel to the surface of the earth but will be more flattened along their polar diameters.

With the exception of a relatively thin intertropical zone, the westerly winds dominate the lower layers of the atmosphere, and hence in these layers the isobaric surfaces are ellipsoids which are more eccentric than the "level" surfaces. Now, as Laplace showed,[1] the atmosphere, assumed to be a fluid and limited by an upper boundary similar to the upper surface of the ocean, extends up to a certain lenticular surface symmetrical with respect to the polar axis of the earth and having an equatorial diameter of 6.6 that of the earth and a polar diameter of 4.4 that of the earth; if, as more recent investigations indicate, the atmosphere has no such limiting fluid surface, but extends out indefinitely beyond the point where attraction and centrifugal force become equal, then the isobaric surfaces approach the practically spherical form due to attraction alone; but in either case the upper air will move under the influence of the friction of the westerly winds of high latitudes and of the easterly winds of tropical regions, the latter exerting the same moment because of their greater distance from the terrestrial axis but relative thinness, the resultant being a movement of the upper air as a solid body with the angular velocity of the earth, so that the rotation of the earth itself can not be altered except by outside influences. Hence it is seen that the exaggerated ellipticities of the lower isobaric surfaces do not continue to extreme heights, but are gradually reduced.

As a consequence, it is at once evident from a diagram that near the surface of the earth the thickness of the stratum between two isobaric surfaces is greater at the Equator than at the poles; but in the upper air, greater at the poles than at the Equator. This thickness, of course, must vary as the specific volume, or as the temperature, of the air. Hence, from the observed wind movements alone, we are led to infer that the surface temperature must increase from poles to equator; but, further, *we must also infer that at sufficiently great heights the temperature increases from Equator to poles.*[2]—*E. W. W.*

[1] See Hann, *Lehrbuch*, 3d ed., p. 2; Milham, *Meteorology*, p. 20; MONTHLY WEATHER REVIEW, 47, 452, 1919.

THE ULTRA ATMOSPHERES.

By T. C. CHAMBERLIN.

[Abstracted from "The Origin of the Earth," University of Chicago Press, 1916, pp. 10–37.]

The constitution of gases is a matter of great importance to meteorology and to cosmogony. Because of the rapid progress which has been made in our knowledge since the time of Laplace, the works of the latter on the atmospheres of the planets, including that of the earth, and on cosmogony, need revision.

The sun, by virtue of its superior attraction, rules the whole space of the solar system: there is merely reserved a small spheroid about each planet in which the attraction of the latter predominates. This "sphere of control" of the earth is a spheroid of three unequal axes, the minimum of which is about 1,000,000 kilometers long and the maximum of which is about 1,500,000 kilometers long. A mass projected into the field of force within this spheroid will describe an ellipse, parabola, or hyperbola (returning to the earth in the first case), according to the velocity with which projected.

The gravity of the earth, as evidenced by the sphere of control, is the holding power of the earth so far as an atmosphere is concerned: the extent and distribution of the atmosphere will depend upon the motions of the individual molecules composing it. The motions and collisions of gaseous molecules can be treated by the methods of statistics and probabilities: and it is easily shown that at times the speeds of certain proportions of the molecules will rise above the mean velocity to given higher and higher velocities up to a theoretically infinite speed for a vanishingly small number of molecules.

The collisional zone.—No matter how great a velocity a molecule may acquire in the lower atmosphere, or how often it may do so, it can only have its motion damped again by plunging into the surrounding multitudes of molecules; in these lower levels the paths of individual molecules are very short and consequently practically straight. Higher up, where the density of the air is less and the molecules sparser, the paths between collisions become longer and slight curvatures begin to appear in response to the forces arising from the earth's attraction.

The krenal zone.—Still higher up, where the molecules are widely scattered, the curvatures grow more pronounced. When the scattered condition becomes still greater, the earth's gravity may stop the outward flight

[2] It would seem that other factors also enter into bringing about this condition. See W. J. Humphreys, "The coldest air covers the warmest earth," in *A Bundle of Meteorological Paradoxes*, Jour. Wash. Acad. Sci., 10, 153–171, 1920 (abstracted in MONTHLY WEATHER REVIEW, 47, 876, 1919). For the probable movements of the *individual molecules* in the extreme upper regions, see T. C. Chamberlin, *Origin of the Earth*, Chicago, 1916, pp. 10–37.—*E. W. W.*

of some molecules, that have rebounded outward, before the next collision takes place, and turn them back on elliptical curves toward the earth. When, with still further ascent, the air grows attenuated enough, these outward flights and returns without collision come to be the dominant feature. The whole summit of the atmosphere is a mass of vaulting molecules, describing loops of all forms, dimensions, and directions. This zone extends from the collisional zone to the outer limit of the sphere of control; some of the vaulting molecules will reach the limit of the sphere, some will go beyond, but the greater multitude will fall short by various degrees. It is wise to emphasize the extremely scattered state of the krenal molecules, especially in the outermost part of the zone, but it is an error to ignore their existence or their importance for many problems. The krenal zone, because of its extreme attenuation, may be called an ultra atmosphere.

The orbital zone.—Collisions are certain to take place in the krenal zone, and by the laws of probabilities the rebounds will in some cases be such that the molecules will then move more or less parallel to the surface of the earth, and a certain proportion of these will have velocities such as to carry them into stable orbits about the earth, in which they will circulate indefinitely until by chance another collision is suffered. An orbital ultra-atmosphere is thus established in the outer portion of the sphere of control: evidently such a condition can not exist in the collisional zone nor in the denser parts of the krenal zone.

A vaulting molecule endowed with the parabolic velocity will, if suffering no collision, go out of the sphere of control and enter into an orbit about the sun; but collisions suffered by orbital molecules may so modify the orbits as to send some of these molecules out of the sphere also, and these modifications may be brought about by a series of successive, relatively insignificant, changes in the orbits. Molecules lost to the earth in the latter way must again pass through the point of collision and in so doing may eventually be captured again by another fortuitous collision; furthermore, the krenal and orbital phases of the solar atmosphere envelop the atmospheres of all the planets; the earth may gain molecules which never before belonged to it, by collisions between solar molecules and molecules of the ultra atmosphere through which they are passing. An equilibrium tends to be established between the ultra-atmospheres of the planets and the sun, for if one becomes more plethoric than is concordant with its relations to the other, it will feed more into the leaner than it will gain from the leaner.

Serious corrections are thus necessary to the current ideas as to the origin, retention, and loss of planetary atmospheres as set forth by Stoney.[1]—*E. W. W.*

[1] See Milham, *Meteorology*, 1914, pp. 15–16; Hann, *Lehrbuch*, 3d ed., 1914, p. 2; Young-*General Astronomy*, 4 Rev. ed., 1904, pp. 181–182; Stoney, *Transactions of the Royal Dublin Society*, 1892, 1897, and 1898, and *Astrophysical Journal*, 11, 36, 1900; *ibid.*, 11, 251, 1900; *ibid.*, 11, 325, 1900; *ibid.*, 12, 201, 1900.

ON THE TEMPERATURE OF THE UPPER STRATA OF THE ATMOSPHERE.

By V. BJERKNES.

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Upon passing from the troposphere into the stratosphere there is encountered an inversion of temperature, and air movements which are very feeble relative to the surface of the earth; it is easy to find the differential equation of such a surface of discontinuity at which the density of the air and the angular velocity around the axis of the earth both change suddenly. This equation shows that if the density changes, but not the velocity, the surface will coincide with an isobaric surface. In the case of the tropopause, the density of the lower layer is greater than that of the upper; and the angular velocity of the stratosphere does not differ greatly from that of the earth, while that of the upper strata of the troposphere is much greater except in a narrow zone on each side of the Equator and possibly at the poles; hence it comes about that the surface of separation is more flattened along the polar diameter than are the isobaric surfaces of the troposphere, these latter in turn being more flattened than the "level" surfaces, and therefore the tropopause is found at a higher level near the Equator than near the poles.

Similarly, it is easily seen that the angular velocity of the air in a cyclone is greater, and that of the air in an anticyclone is less, than the component of the angular velocity of the earth about the same axis; cyclones and anticyclones being local formations not extending into the stratosphere, it follows[1] that in the highest parts of a cyclone the temperatures will be greater, and in the highest regions of an anticyclone they will be lower, than elsewhere at the same levels; and from the equation referred to above it appears that the tropopause has a depression above a cyclone and an elevation above an anticyclone; these elevations and depressions are not the causes of the formations, but merely the effects of the air movements.[2]—*E. W. W.*

WINDS AND TEMPERATURE GRADIENTS IN THE STRATOSPHERE.[1]

By G. M. B. DOBSON.

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Some years ago observations by "ballons-sondes" showed that while the troposphere is colder in cyclones than in anticyclones, the reverse is the case in the stratosphere, and it was pointed out that as a consequence of this the wind velocity must be reduced in the lower part of the stratosphere. Data obtained from 70 cases where "ballons-sondes" had been followed by theodolites to heights well within the stratosphere and had given satisfactory temperature and pressure records were plotted, *heights being referred to the tropopause, thus causing the elimination of effects due to the variation in the height of the base of the stratosphere above mean sea level.* The resulting diagrams show very clearly that which is not shown when heights are referred to mean sea level, viz, the remarkable suddenness of the changes which take place at the tropopause.

The wind velocity within the troposphere increases with height at a rate roughly inversely proportional to the density, i. e., at a rate which would occur if the pressure gradient remained constant. It may be taken as a general rule that whenever the velocity is fairly large, say, 15 m/s, in the troposphere, it almost invariably decreases very suddenly within the stratosphere; for winds under

[1] *C. R.*, 170, 604, 1920.

[2] J. V. Sandstrom has considered the same questions, and by a less direct analysis has been led to the same conclusions; see Ueber die Beziehung zwischen Temperatur und Luftbewegungen in der Atmsophare unter stationaren Verhaltnissen, Ofversigt af k. Vetenskaps Akkademien Forhandlinger, Stockholm, 1901; and Ueber die Temperaturwerteilung in den aller hochsten Luftschichten, Arkiv. for Math., Astr. och Fysik, Stockholm, 1907. On the physical causes of the occurrence and position of the tropopause, see W. J. Humphreys, Physics of the Air, and in another form in MONTHLY WEATHER REVIEW, 1919; 47, 162–163, and Science, 49, 156–163, 1919.

[1] Cf. a shorter abstract in the REVIEW, Jan. 1920, 48: 11.